Although classical wave configurations are examples of ephemerals this does not mean that the elementary 'particles' are just waves. ~~They do not possess~~ ~~TI~~ We ~~shall~~ have argued that they do not in fact possess TI. So the substantial aspect of particles is lacking for the elementary 'particles'. But like the Cheshire Cat, although the substantial 'particularity' has gone, there remains a particle 'grin'. The elementary 'particles' are not particles but they are also not classical-type fields — they are quantum fields — ephemerals with a particle 'grin' — (and if you want me to stick my neck out) this is the ultimate nature of reality according to modern theoretical physics.

Field Quantization ⑱

We ~~one~~ Fourier analyse the ~~the~~ state of the field in terms of the excitation of various possible modes labelled by a wave-vector $\underline{k}$.

On quantizing the field the ~~total~~ energy associated with these excitations can take on discrete values characterized by the integral values of the excitation number $n_{\underline{k}}$.

⑫ The energy of each mode changes in units of $(\hbar\omega_k)$ where $\hbar$ is Planck's constant and ω_k ~~$= c\sqrt{\mu^2+k^2}$~~ is the angular frequency of the mode.

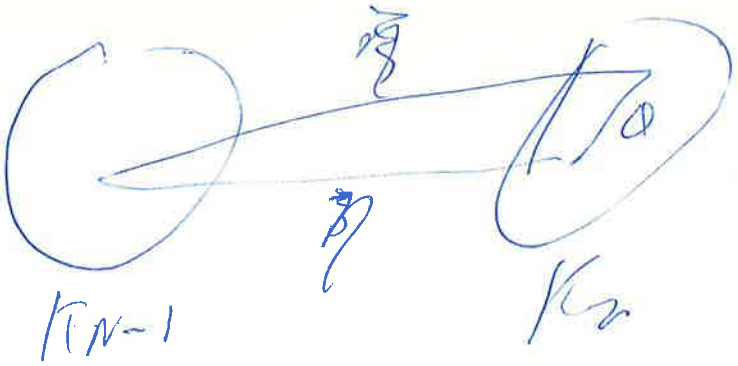
⑬ The Particle representation specified by definite $n_{\underline{k}}$ is one in which the total energy, momentum of the field ~~are~~ diagonal, i.e. have sharp values

We then have the same result as QFT.

The number of particles (quanta) present will remain the no. [illegible] in the particle [illegible] [illegible] the quantum modes [illegible]

(20) Creation & annihilation operators which act on decrease the quantum numbers by one unit

(21) Creation / annihilation operators in the quantization —



Fields $a = \xi \cdot \eta$

creation operators

annihilation operator

operators like $\xi + \eta$ describe creation & annihilation of particles

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Wave - Particle Duality:

In QFT complementarity ~~reasserts itself~~ appears between the particle picture in which the total energy, momentum & the field have sharp values and the wave picture in which the field amplitude & other local quantities are sharp.

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The Vacuum

this is the state for which all the $n_{\underline{a}}$ are zero. It is the *lowest* energy state of the field. But the energy is not zero, since the field amplitude and other local quantities exhibit *vacuum fluctuations*. the non-vanishing energy of the vacuum is called the *zero-point energy* of the field